The Victorian Naturalist

Volume 134 (5) October 2017

Published by The Field Naturalists Club of Victoria *since 1884*

From the Editors

The articles published in this issue of the journal demonstrate features that are fundamental to the study of natural history. The first of these is fieldwork. Studies such as those reported here by Turner, Drury, Annable and Monger cannot be done from the comfort of one's living room. The second is the enormous diversity that natural history studies can encompass, which is demonstrated by the papers collectively. This is particularly the case with Drury's results of a biodiversity survey of some of Melbourne's parks and reserves, which is also a wonderful example of a collaborative citizen-science exercise, with Parks Victoria.

This fortuitous collection of articles is further evidence—if such was needed—that studies within the realm of natural history range from the macro to the micro. In this case, the focus shifts from species detected in a survey, to specific behaviour by individual creatures. Interestingly, in two of these reports the behaviour relates to specific sensory abilities.

The Victorian Naturalist
is published six times per year by the

Field Naturalists Club of Victoria Inc
Registered Office: FNCV, 1 Gardenia Street, Blackburn, Victoria 3130, Australia.
Postal Address: FNCV, PO Box 13, Blackburn, Victoria 3130, Australia.
Phone +61 (03) 9877 9860;
email: admin@fncv.org.au
www.fncv.org.au

Patron: Her Excellency, the Governor of Victoria

Address correspondence to:
The Editors, *The Victorian Naturalist*, PO Box 13, Blackburn, Victoria 3130, Australia.
Phone: (03) 9877 9860. Email: vicnat@fncv.org.au

Yearly Subscription Rates – The Field Naturalists Club of Victoria Inc

Membership category

Single	$ 84	Institutional	
Family	$109	- within Australia	$167
Single Country/Concession	$ 63	- overseas	AUD180
Family Country/Concession	$ 84		
Junior	$ 50		
Junior additional	$ 17	Schools/Clubs	$96
Student	$ 38		

All subscription enquiries should be sent to:
FNCV, PO Box 13, Blackburn, Victoria 3130, Australia

Phone 61 3 9877 9860. Email: admin@fncv.org.au

The

Victorian Naturalist

Volume 134 (5) 2017 October

Editors: Gary Presland, Maria Gibson, Sue Forster

Editorial Assistant: Virgil Hubregtse

ISSN 2208-6277

Front cover: Powerful Owl *Ninox strenua*. Photo: Sally Bewsher.
Back cover: Spotted Marsh Frog *Limnodynastes tasmaniensis*. Photo: Grant S Turner.

The Plague Minnow *Gambusia holbrooki* as a predator of Spotted Marsh Frog *Limnodynastes tasmaniensis* tadpoles

Grant S Turner

103 Settlement Road, Bundoora, Victoria 3083

Abstract

The predatory behaviour of the Plague Minnow *Gambusia holbrooki* on Spotted Marsh Frog *Limnodynastes tasmaniensis* tadpoles in the field is described. *Gambusia holbrooki* was observed to consume small (hatchling) *L. tasmaniensis* tadpoles whole and to repeatedly attack larger tadpoles by nipping at their tail-fins and developing limbs, often resulting in a significant reduction in tail area (median reduction 30–40%) and, sometimes, death. (*The Victorian Naturalist* **134** (5), 128-131)

Keywords: *Gambusia holbrooki*, *Limnodynastes tasmaniensis*, tadpoles, predation, tail-fin

Introduction

The Plague Minnow (or Eastern Mosquito Fish) *Gambusia holbrooki* is a small (maximum length 60 mm) freshwater fish that is native to North America; through both deliberate and inadvertent introductions, it has become naturalised throughout many Australian waterways (Pyke 2008; White and Pyke 2011). It is considered a significant pest species, competing with native fish and preying on aquatic invertebrates, native fish and amphibian eggs and tadpoles (see Pyke 2005, 2008). Gillespie and Hero (1999) recorded *G. holbrooki* as a predator of the eggs and/or tadpoles of 11 species of Australian frogs. An experimental study has shown *G. holbrooki* to prey on small Spotted Marsh Frog *Limnodynastes tasmaniensis* tadpoles (Harris in Gillespie and Hero 1999), but field observations of such predation have not to my knowledge been reported.

Here I document two series of field observations, made in northern suburban Melbourne in 1988-89, of *G. holbrooki* predation on *L. tasmaniensis* tadpoles, and I describe their predatory behaviour. I use the term 'predation' throughout to include not only consumption of whole tadpoles but also injuries — fatal or non-fatal — caused by fish attacks.

Site descriptions

The first series of observations were made in my backyard at Bundoora, 15 km north-east of Melbourne, in a small plastic outdoor pond, from mid-September to mid-December 1988. The pond had a surface area of approximately 1 m^2 and a maximum depth of 300 mm. *Gambusia holbrooki* was present in a nearby above-ground swimming pool whose water was not chemically treated during the cooler months, and was noted in the small pond in September. *Limnodynastes tasmaniensis* bred in the pond in October 1988.

The second series of observations was made 1.4 km away in a natural wetland in Thomastown (37°41'10"S, 145°02'22"E; 103 m asl) from late December 1988 to late January 1989. The wetland included two swamps about 40 m apart: one that was permanent and approximately circular (diameter 20 m); the other shallow, ephemeral (maximum length 50 m), and typically dry from mid-to-late summer to mid-to-late autumn. Both swamps had predominantly native aquatic vegetation and the wetland supported open stands of mature River Red Gum *Eucalyptus camaldulensis* with a degraded grassy understorey. The wetland was bounded on the east side by Darebin Creek and on the south side by a minor tributary; it has since been destroyed by housing development.

Rain in early January 1989 caused flooding, which resulted in the two swamps being temporarily joined. As flood waters receded, small pools formed in ground depressions in the land separating them. These were utilised as breeding sites by *L. tasmaniensis*, the Common Eastern Froglet *Crinia signifera* and Ewing's Tree Frog *Litoria ewingii*. *Gambusia holbrooki* was resident only in the permanent swamp at the time, but flooding resulted in its spread into some of the ponds in the connecting strip.

Methods

The tadpoles of *L. tasmaniensis* are lentic in habit and generally take three to five months to metamorphose (Martin 1965; Horton 1982; Anstis 2013), but in summer (around Melbourne) metamorphosis can be completed in six to eight weeks (pers. obs.). Eggs and tadpoles were identified using Martin (1965) and Martin *et al.* (1966); tadpoles were staged using Gosner (1960).

Fish and tadpoles in the backyard pond were observed directly from above (at an oblique angle) with minimal disturbance. They were provided with boiled lettuce, fish flakes and occasionally fish pellets. In the wetland pond, observation of fish and tadpoles was not possible because the water was too turbid. A small dip-net (1.5 mm mesh) was used to collect fish and tadpoles from ponds for examination and measurement. The total lengths of *G. holbrooki* and snout-to-vent lengths (SVL) of tadpoles were measured to 1 mm by placing individuals on a wet plastic surface and gently aligning them with a 150 mm stainless steel ruler.

To quantify the injuries to tadpoles inflicted by *G. holbrooki*, the missing area of the tail (comprising fins and myomeres) was estimated to 10% by comparing it to the outline of a complete tail traced from a photograph onto an overhead transparency. The tail-fin of the tadpoles was thin, pliable and easily torn; bite marks were obvious. The body, rear limb-buds and limbs of metamorphosing tadpoles were examined for injuries using a hand-lens (×10). After study, all *G. holbrooki* (collected at both sites) were euthanised.

Observations

Backyard pond

A foam nest containing approximately 400 eggs was deposited in the pond in early October; eggs hatched within a fortnight. While some *G. holbrooki* appeared to feed on the egg mass, the effects of predation on this stage were not significant and the mortality of small numbers of eggs (< 5% of the egg mass) was possibly due to other reasons (e.g. unfertilised eggs, fungal attack); the integrity of the egg mass was not affected. By contrast, hatchling tadpoles were readily consumed in large numbers even by quite small *G. holbrooki*. In one instance, 36 six-day-old tadpoles with SVL 10 mm (Gosner Stage 21) were consumed by five *G. holbrooki* (one, a 45 mm adult; the remainder < 30 mm in length) within eight minutes. The tadpoles were eaten whole, despite the presence of alternative food items. At least five tadpoles completed metamorphosis, but had trimmed digits on the rear limbs, as well as abdominal lesions resulting from *G. holbrooki* bites.

Gambusia holbrooki employed several predatory tactics. The fish generally swam at mid-water depths. This provided a good vantage point on the tadpoles, which spent most time near the bottom. Tadpoles fed mainly on food that had sunk to the substrate and periodically left it briefly to gulp air at the surface. When tadpoles were moving (either across the substrate or up to the surface), fish were quick to respond to their movements and pursued them, being significantly faster and more agile. Small tadpoles (<12 mm in total length) were approached from the rear and consumed whole (tail first). Larger tadpoles were attacked intermittently over days or weeks, being repeatedly bitten on the tail-fins. Fish typically approached tadpoles slowly from the rear and, when within about 10 mm, darted at the tadpoles and nipped the tail-fin. This usually caused tadpoles to swim rapidly along the substrate, stirring up a cloud of debris. After several days, some tadpoles showed a significant reduction in tail-fin area (> 20%) and, in more extreme cases, the tail myomeres were also damaged (16% of a random sample of 30 tadpoles). There was some minor damage to limb buds (n=3) but their small size and position afforded them some protection. Fish directed their attacks to the larger, more developed limbs of late-stage and metamorphosing tadpoles (Gosner Stage 35-41), consuming the digits and, in some instances, entire limb-buds. Large reductions in the tail-fin area (> 50%) were observed to reduce tadpole mobility to the extent that movements to the surface were impossible. This incapacity may have resulted in the deaths of some tadpoles (n=6). Other deaths appeared to result from the direct effects of the injuries inflicted by fish, such as ruptures of the abdominal wall (n=3). Dead tadpoles were consumed in all cases by fish, leaving only cartilaginous remains.

On three occasions *G. holbrooki* was also observed to flush tadpoles from the substrate. When motionless on the substrate, tadpoles were not readily detected by fish. In flushing, adult fish dived from mid-water into substrate debris in a broad arc, scooping and stirring it up. Tadpoles responded hy swimming a short distance away before settling again and, on all occasions, fish then moved directly to where tadpoles had settled and promptly attacked them by nipping their tail-fins.

Wetland pond

On 18 January 1989 I examined the entire contents of a pond that had formed in an old wheel rut along a vehicle track between the two swamps. The pond measured 8.50 × 0.25 m, had a maximum depth of 0.13 m and the water was very turbid. Prior to flooding, two *L. tasmaniensis* egg masses, each with 400-600 eggs, had been deposited in the pond, and *G. holbrooki* was absent. Approximately two weeks after the eggs hatched, flooding enabled *G. holbrooki* to enter the pond.

In total, 84 *G. holbrooki* were removed from the pond. Nearly all (96%; n = 81) were 18-30 mm in length. The largest specimen was a gravid female measuring 47 mm. In total, 87 *L. tasmaniensis* tadpoles were removed and their SVLs ranged from 7-18 mm (Gosner Stage 28–42; nearly 80% were at Gosner Stage 28-32). All tadpoles exhibited tail and rear limb-bud damage. The nature and extent of injuries on larger tadpoles were identical to those observed in the backyard pond. Tail-fin damage was far more common, since most tadpoles had only small rear limb-buds. The distal portion of the tail and the dorsal fin were most frequently damaged (Table 1). Most tadpoles (57%) had approximately 30–40% of the distal tail-fin missing. In all instances where the tail-fins exhibited > 50% damage, the myomeres were also damaged. One of the tadpoles, exhibiting 50% tail-fin damage, was dead. Some 15% of individuals (n=13) had small ruptures of the abdominal wall, consistent with bites from fish as observed in the backyard pond. Only three individuals had well-developed rear limbs (Gosner Stage 40–42) and two of these had all digits trimmed, leaving only a stub. Two *C. signifera* tadpoles (Gosner Stage 40, 42) were also located in the pond: one did not exhibit any signs of injury while the other had minor tail-fin damage (< 10%).

Limnodynastes tasmaniensis tadpoles in nearby fish-free ponds did not exhibit any of the injuries described, despite being in higher densities, indicating that the injuries resulted from the presence of *G. holbrooki* rather than intraspecific overcrowding or the presence of aquatic invertebrate predators (none was located in the ponds).

Discussion

This study has confirmed that *G. holbrooki* can be a significant predator of *L. tasmaniensis* tadpoles in Australia. Fish attacked *L. tasmaniensis* tadpoles at all stages of development, with small tadpoles being consumed whole, and larger tadpoles being repeatedly, sometimes fatally, hitten on the tail-fin and/or developing limbs. The consumption of tadpoles from three egg masses was near-total and recruitment into the adult population therefore minimal. Tail damage caused by *G. holbrooki* has been shown to potentially affect survivorship of other tadpole species by increasing the length of time they take to complete metamorphosis and by increasing their susceptibility to further attacks (Semlitsch 1990; Blair and Wassersug 2000).

My observations suggest that *G. holbrooki* relies primarily on vision to detect prey in clear water; it is therefore not surprising that it is preferentially attracted by moving prey (see Pyke 2005 and references therein). However, it is evident that turbid water does not protect *L. tasmaniensis* tadpoles from *G. holbrooki* attacks, at least in small waterbodies. *G. holbrooki* has little ability to detect vibrations and disturbances (Pyke 2005), so presumably the fish relies on tactile and/or olfactory stimuli in this situation.

Table 1. Frequency of Spotted Marsh Frog *Limnodynastes tasmaniensis* tadpoles in categories representing the percentage of the tail area that is missing (n=87).

< 20%	20 - < 30%	30 - < 40%	40 - < 50%	> 50%
1	12	49	22	3

To what extent substrate colour-matching protects *L. tasmaniensis* tadpoles from *G. holbrooki* predation is unclear. Tadpoles were observed to vary considerably in colour depending on the waterbody they inhabited (pers. obs.; see also Anstis 2013). For example, at the wetland site, *L. tasmaniensis* inhabiting ponds with surface mats of *Azolla pinnata* (as in the larger swamp) were dark brown to almost black in colour, whereas those inhabiting turbid pond water were cream-beige.

While *G. holbrooki* generally prefers invertebrate prey to tadpoles (Gillespie and Hero 1999 and references therein; Lawler *et al.* 1999), it can nonetheless be an efficient predator of tadpoles. Predation by *G. holbrooki* has been documented as occurring at all pre-metamorphic stages of development, although its impact tends to be greatest on hatchlings and small tadpoles, rather than on eggs, which in some species are unpalatable to fish (Gillespie and Hero 1999 and references therein; Smith and Smith 2015). Webb and Joss (1997) observed that tadpoles of the Striped Marsh Frog *Limnodynastes peronii* were most susceptible to predation by *G. holbrooki* immediately following hatching, when they hang vertically and immobile beneath the egg mass. The consumption of *L. tasmaniensis* tadpoles after killing contrasts with the observations of Pyke and White (2000) that large killed tadpoles of Green and Golden Bell Frog *Litoria aurea* were rarely eaten. These authors also report *G. holbrooki* attacking from the rear, usually in a school, rather than as individuals. The tactic of nipping at the fins of larger prey is also employed by *G. holbrooki* when attacking fish (Cadwallader and Backhouse 1983).

In this study I observed seven frogs with trimmed rear digits at the wetland site. Three sub-adult and two adult *L. tasmaniensis* and two adult Southern Bell Frogs *Litoria raniformis* exhibited trimmed digits on one (n=1) or both (n=6) rear feet. Given the resemblance to the trimmed digits seen in metamorphling *L. tasmaniensis*, it is possible that these injuries result from *G. holbrooki* attacks during the tadpole stage rather than occurring after metamorphosis. A knowledge of the regenerative capacity of the digits of growing frogs, and a comparison of the incidence and pattern of rear limb toe loss in areas where *G. holbrooki* is present or absent, is needed to determine whether toe loss has the potential to be used as an indirect measure of *G. holbrooki* predation.

Acknowledgements

I thank Paul Humphries for correcting and improving the draft manuscript.

References

Anstis M (2013) *Tadpoles and Frogs of Australia.* (New Holland Publishers: Sydney, NSW)

Blair J and Wassersug RJ (2000) Variation in the pattern of predator-induced damage to tadpole tails. *Copeia* **2000**, 390–401.

Cadwallader PL and Backhouse GN (1983) *A Guide to the Freshwater Fish of Victoria.* (Victorian Government Printer: Melbourne)

Gosner KL (1960) A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* **16**, 225–232.

Gillespie GR and Hero J-M (1999) Potential impacts of introduced fish and fish translocations on Australian amphibians. In *Declines and Disappearances of Australian Frogs,* pp. 131–144. Ed A Campbell. (Environment Australia: Canberra)

Horton P (1982) Precocious reproduction in the Australian frog *Limnodynastes tasmaniensis. Herpetologica* **38**, 486–489.

Lawler SP, Dritz D, Strange T and Holyoak M (1999) Effects of introduced mosquitofish and bullfrogs on the threatened California Red-legged Frog. *Conservation Biology* **13**, 613–622.

Martin AA (1965) Tadpoles of the Melbourne area. *The Victorian Naturalist* **82**, 139–149.

Martin AA, Littlejohn MJ and Rawlinson PA (1966) A key to the Anuran eggs of the Melbourne area, and an addition to the Anuran fauna. *The Victorian Naturalist* **83**, 312–315.

Pyke GH (2005) A review of the biology of *Gambusia affinis* and *G. holbrooki. Reviews in Fish Biology and Fisheries* **15**, 339–365.

Pyke GH (2008) Plague minnow or mosquito fish? A review of the biology and impacts of introduced *Gambusia* species. *Annual Review of Ecology, Evolution, and Systematics* **39**, 171–191.

Pyke GH and White AW (2000) Factors influencing predation on eggs and tadpoles of the endangered Green and Golden Bell Frog (*Litoria aurea*) by the introduced Plague Minnow (*Gambusia holbrooki*). *Australian Zoologist* **31**, 496–505.

Semlitsch RD (1990) Effects of body size, sibship, and tail injury on the susceptibility of tadpoles to dragonfly predation. *Canadian Journal of Zoology* **68**, 1027–1030.

Smith GR and Smith LE (2015) Effects of Western Mosquitofish (*Gambusia affinis*) on tadpole production of Gray Treefrogs (*Hyla versicolor*). *Herpetological Conservation and Biology* **10**, 723–727.

Webb C and Joss J (1997) Does predation by the fish *Gambusia holbrooki* (Atheriniformes: Poeciliidae) contribute to declining frog populations? *Australian Zoologist* **30**, 316–324.

White AW and Pyke GH (2011) World War II and the rise of the plague minnow *Gambusia holbrooki* (Girard, 1859) in Australia. *Australian Zoologist* **35**, 1024–1032.

Received 29 April 2017; accepted 17 August 2017

A community-based biodiversity survey in the parks and reserves of eastern and south-eastern Melbourne—results and perspective

Fauna Survey Group Contribution No. 29

Robin Drury

Fauna Survey Group, Field Naturalists Club of Victoria,
PO Box 13, Blackburn, Victoria 3130
Email: robindrury6@gmail.com

Abstract

Parks Victoria and the Field Naturalists Club of Victoria, with the assistance of members of local community groups and organisations, undertook a survey of vertebrate fauna in 16 parks and reserves to the east and south-east of Melbourne. The survey included terrestrial and arboreal mammals, as well as bats, frogs and reptiles. No formal bird survey took place, although birds identified during other surveys were recorded. Those techniques comprised the use of remote cameras, bat traps, hair funnels, spotlighting, the monitoring of tile and tin grids and aural frog surveys. Along with Parks Victoria staff, over 100 volunteers affiliated with some 26 groups, carried out fieldwork and data analysis. There were 114 different species identified, comprising 64 birds, 29 mammals (including eight bat species), 10 frogs and 11 reptiles. The project demonstrated that community groups can make a significant contribution to biodiversity monitoring. The data collected, plus observations gathered from other sources, show that these reserves have the opportunity to make a solid contribution to the conservation of native biota. Monitoring is an integral part of this conservation effort. (*The Victorian Naturalist* 134 (5), 132-149)

Keywords: Urban parks, community involvement, urban biodiversity, biodiversity monitoring, citizen science

Introduction

Parks Victoria (PV) is a statutory organisation responsible for managing nearly 3000 parks, conservation reserves and natural features throughout the State of Victoria (Parks Victoria 2015a). It is estimated that these areas provide a home for some 4300 native plant and 948 native animal species (Parks Victoria 2015b). Key management directions for the organisation include the conservation and restoration of habitats, the reduction of over-abundant and invasive plant and animal species and a focus on habitats for threatened species (Parks Victoria 2013).

Whatever conservation action is put in place, it 'must be measured by rigorous monitoring and reporting on trends in species populations, ecosystems and threats' (Lindenmayer *et al.* 2012). This biodiversity monitoring provides guidelines for decision-making and allows the measurement of progress over space and time (Niemelä 2000). However, Bell *et al.* (2008) acknowledge that resourcing the gathering of biodiversity information is a general problem and suggest that demand has outstripped the capacity of professional scientists and that the cost is prohibitive. In Australia lack of government support for biodiversity monitoring has contributed to this problem (Lindenmayer *et al.* 2012). Given that there have been large biodiversity monitoring projects which owe their success to the contribution of volunteers or citizen scientists (Schmeller *et al.* 2009, Bonney *et al.* 2009), the use of volunteer labour provides a real opportunity to meet this excess demand.

In this context the Fauna Survey Group (FSG) of the Field Naturalists Club of Victoria (FNCV) volunteered to assist Parks Victoria with a vertebrate fauna survey in parks and reserves to the east and south-east of Melbourne. Drury (2014) outlined the project's background and aims. Some changes to the original proposal occurred, with fewer reserves and focus areas actually covered. Also, lack of resources meant that no specific audio or visual bird surveys could be completed, although bird presence was recorded during other types of survey.

This survey covered three parkland complexes: Berwick, Dandenong Valley and sandbelt,

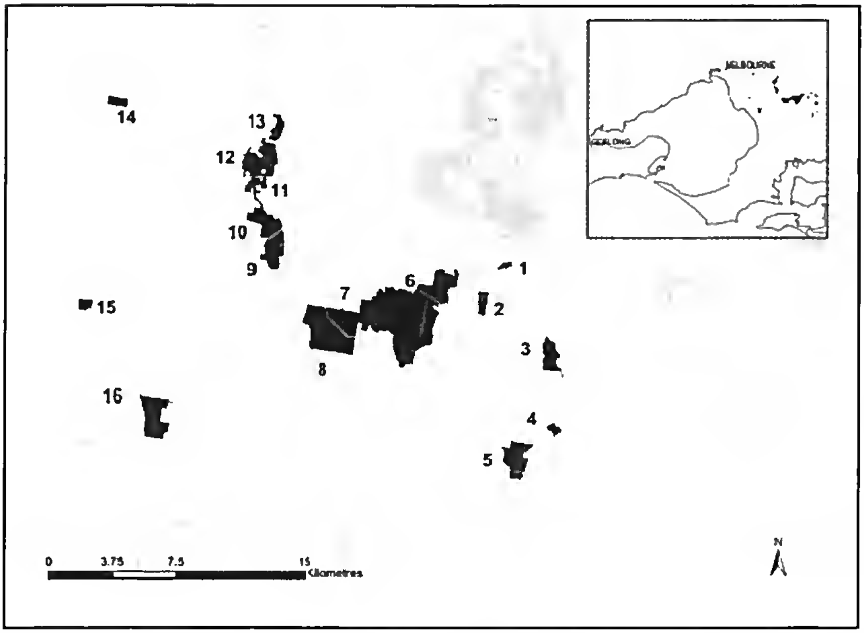

Fig. 1. Map of the study area. (1. Selby G190 BR, 2. Baluk Willam, 3. Cardinia Creek Reservoir, 4. Upper Beaconsfield NCR, 5. Cardinia Creek Parklands, 6. Lysterfield Park, 7. Churchill National Park, 8. Dandenong Police Paddocks, 9. Corhanwarrabul Wetlands, 10. Jells Park, 11. Shepherds Bush, 12. Bushy Park Wetlands, 13. Koomba Park, 14. Wattle Park, 15. Karkarook Park, 16. Braeside Park. Areas in pale grey indicate other public land. (Supplied by Parks Victoria)

and included a total of 16 parks, bushland reserves (BR) and nature conservation reserves (NCR) (Fig. 1). In this paper these will be generically referred to as reserves.

In the north-east of the study area, Wattle Park in suburban Burwood is used largely for recreation but has a small conservation area at its eastern end. Some 10 km to the east is Koomba Park, which has Boronia Rd as its northern boundary and marks the northern end of the Dandenong Valley Parklands. From Koomba Park, this parkland follows the Dandenong Creek in a southerly direction through Bushy Park, Nortons Park (not surveyed), Shepherds Bush, Jells Park and Corhanwarrabul Wetlands. These reserves occur in an urbanised part of Melbourne and are separated by major roads. The creek then flows south through open space (including a Melbourne Water retarding basin, other wetlands and recreation areas and a golf course) to Stud Road, where it meets the Berwick parkland at the Dandenong Police Paddocks Reserve.

Dandenong Police Paddocks Reserve, Churchill National Park and Lysterfield Park, make up the largest contiguous component of the study area. While most of the boundaries of these parks are rural or open space, they also provide an example of the urban/rural interface with the typically suburban blocks of Rowville on one side and larger blocks of Hallam North on another. Baluk Willam NCR and Selby G190 BR are outlier reserves a few kilometres from the main reserve to the north, both in a rural setting.

Also in Berwick parklands are Cardinia Creek Parklands and Cardinia Reservoir Park, which flank Cardinia Creek and occur in a largely rural setting. Upper Beaconsfield NCR (Critchley Parker Junior Reserve) is an outlier less than a kilometre from the creek and between the other two reserves.

The sandbelt parkland reserves included in the study were Braeside and Karkarook Parks. Braeside is the larger of the two and is bounded by a mixture of residential, industrial and open

space. Karkarook is a small reserve, similarly bounded.

In total the area of the reserves exceeds 4500 ha, but individually they differ significantly in size. The largest component is Churchill/Lysterfield at 1668 ha and the smallest is Selby at 21 ha.

Forty focus areas of interest were selected by Parks Victoria, based on conservation and pest control issues. Focus areas varied in size. In some cases they consisted of the whole reserve, but in others a number of focus areas were selected within a reserve. The first surveys took place in March 2013. Most of the survey work was completed by April 2014, except for monitoring of the tiles and tin, which continued until the end of 2016.

Methods

The fauna survey

The study recorded the occurrence of birds, reptiles, frogs and mammals, including bats. The survey techniques used (Table 1) were remote cameras, harp trapping, hair funnels, spotlighting, aural frog surveys and the establishment and monitoring of artificial habitat (roof tiles and tin) for reptiles, amphibians and small mammals.

The application of techniques in a focus area depended on the nature of the issues for that area (i.e. conservation or pest species), its geography (e.g. not all had wetlands), the safety of the public and the security of equipment. This meant that not all techniques were deployed in every focus area. In general, the size of the survey effort was related to the size of the focus area. The survey effort for each reserve is summarised in Table 2.

A mixture of Ltl Acorn 6210M and Scoutguard 550V cameras were used for this project. Parks Victoria provided a grid of study waypoints 200 metres apart, in each focus area. There were 307 of these waypoints. The cameras were placed on a tree as close to a point as possible and were focused on a bait station (cage containing a tea infuser containing a mixture of peanut butter, oats and golden syrup as bait) on a plastic garden stake (Macak *et al.* 2012). All cameras were deployed for 21 days and set to video for 10 seconds (around 7 megabytes) with a 3-minute interval before they could be activated by another trigger. The sensitivity level was set to high. Half the cameras in each focus area were deployed in autumn/winter and the other half in spring/summer. Cameras were not deployed at 29 sites where there was either no access (e.g. lake or swamp), no tree within 30 metres of the waypoint, or if the site was considered too exposed to the public. In all, cameras were deployed at 273 sites. Images were uploaded to Dropbox™ for volunteers to review and record the species detected. They were reviewed a second time in cases where the first reviewer had been uncertain of the species, where the detection indicated a small mammal or where the species was 'out of area'. Some of the reviewers noted bird calls, but this had not been requested.

The hair funnels were all Faunatech Universal Hair Funnel (150 mm diameter). The funnels were deployed in rows of 10 and baited with peanut butter, oats and golden syrup. In most focus areas one row of 10 was deployed, but in the larger focus areas this was increased to two or three rows. Rows were between camera sites where the vegetation was thickest. The funnels were deployed only in autumn/winter when reptile activity is lowest. They were deployed for 10 nights at 36 sites.

Spotlighting, using red filters, was undertaken along transects within focus areas. Where possible, this was done along already defined

Table 1. Groups of vertebrate fauna recorded during the survey and survey recording techniques.

Survey technique	Bats	Birds	Frogs	Mammals large	Mammals medium	Mammals small	Reptiles
Remote camera		*		*	*	*	*
Hair funnels					*	*	
Sound recording			*				
Spotlighting	*	*	*	*	*		*
Harp trap	*						
Hand-searching (tiles and tin)			*			*	*

tracks. There were 42 transects in all. Surveys usually lasted one hour. Animals were recorded if they were seen or heard within the first 30 minutes and then in 15 minute blocks thereafter. For safety purposes, areas of thick bush or steep terrain were avoided if there was no track.

Frog surveys were undertaken at wetlands in and around the focus areas and were carried out in accordance with the Melbourne Water Frogwatch program (Melbourne Water 2012). The frog advertisement calls were recorded for five minutes at each site. The surveys were scheduled at 45 sites in August, October and November 2013 and April 2014. Two surveys were scheduled each month, the dates being determined by the survey team. After each survey, the recordings were analysed by a team member to determine the species that had called at each site. The results were entered on a data sheet that included observer details, site information, species and number recorded and time, date and weather information. Recordings and data sheets were forwarded to the survey co-ordinator for review and then forwarded to Melbourne Water for further review and inclusion in their database. Recordings and results were also uploaded to Dropbox™ for the information of surveyors.

Bat trapping was carried out at 36 sites using harp traps. There were usually two traps deployed at each site. In more secluded areas traps were left out overnight, after being checked around 10.30 pm. Security and safety (of animals, traps and park users) was a concern in the more heavily used reserves, where the traps were dismantled after the 10.30 pm check.

Fifty-five artificial shelter quadrats were set up. Each quadrat consisted of 16 roof tiles arranged in a 4 × 4 grid, all tiles two metres apart, plus two or four sheets of corrugated iron, roughly 900 mm × 900 mm, which were placed at each end of the quadrat. The tiles and tin

Table 2. Survey effort by reserve. The asterisk indicates that the focus area is the whole reserve and 'n' is the number of reserves in which that technique was used.

Parkland	Reserve	Focus areas surveyed	Cameras deployed (n=15)	Hair funnel deployed (n=13)	Harp trap sites (n=14)	Spotlight transects (n=14)	Frog sites (n=11)	Reptile quadrats (n=12)
Berwick	Baluk Willam NCR	1*	16	20	2	2	2	4
	Cardinia Creek Parklands (north)	4	13	20	4	3	6	5
	Cardinia Reservoir Park	2	13	20	4	4		1
	Churchill National Park	2	11	20	4	5	3	5
	Dandenong Police Paddocks Reserve	4	28	40	2	2	4	11
	Lysterfield Park	8	101	110	8	10	10	6
	Selby G190 BR	1*	5	10	1	2		
	Upper Beaconsfield NCR	1*	8	10	2	1		
Dandenong Valley	Bushy Park	3	13	30	1	1	1	3
	Corhanwarrabul Wetlands	1*	7					3
	Jells Park	4	19	10	3	3	3	4
	Koomba Park	1*	8		2	2	4	2
	Shepherds Bush	1*	5	10	1	2	2	2
	Wattle Park	1	2	10	1	1		
Sandbelt	Braeside Park	4	24	50	2	4	6	10
	Karkarook Park	2					4	
	Total surveys	40	273	360	36	42	45	55

were checked six times between October 2014 and December 2016.

All records were entered into the Victorian Biodiversity Atlas.

Community involvement

Community involvement took place at two levels: project management and fieldwork. The project management component was carried by FSG, along with PV.

Project management involved survey design, grant applications, community and management briefings, training of staff and volunteers, communication with volunteers, activity scheduling, management of field visits data, equipment preparation, analysis and management, and report preparation.

Fieldwork opportunities were provided for volunteers as follows:

- The deployment of cameras and hair funnels;
- Analysis of camera images, which had been uploaded onto Dropbox for ease of distribution and access;
- Participation in spotlighting and bat trapping;
- Participation in aural surveys for frogs, supported by a Melbourne Water training session. These results have also been placed on Dropbox for information and training purposes;
- Participation in training sessions for tile and tin deployment for reptile surveys;
- Checking tin and tiles.

Community engagement commenced with information sessions at each of the three parklands, thus providing an overview of the project for interested parties. Email lists were developed to contact participants about activities and the extent of their interest. A progress session was held in December 2013 and another feedback session in November 2014, after most of the results were available.

Results

The fauna survey

Over 9800 vertebrate animal detections were made with identification to species level and 460 more to genus level or above. Detections by camera accounted for 85% of the total. There were 115 different species identified, comprising 64 birds, 29 mammals (including eight bat species) 10 frogs and 12 reptiles. Table 3 shows the occurrence of the species by reserve and the number of reserves in which a species was detected.

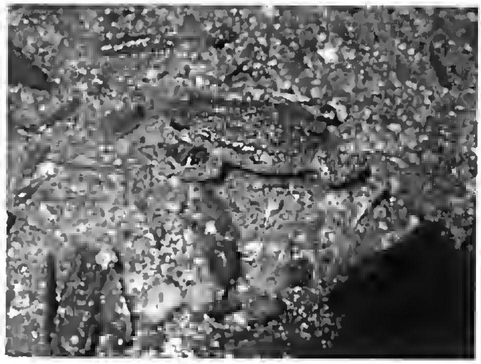

Fig. 2. Southern Toadlet *Pseudophryne semimarmorata*. Photo: Robin Drury.

Recorded species of conservation significance (DSE, 2013) were: vulnerable Grey-headed Flying-fox *Pteropus poliocephalus* and Powerful Owl *Ninox strenua* (cover image), both recorded at five reserves, and Southern Toadlet *Pseudophryne semimarmorata* (Fig. 2) recorded at two reserves.

Near-threatened Nankeen Night Heron *Nycticorax caledonicus hillii* and Latham's Snipe *Gallinago hardwickii* were recorded at one reserve each.

Pteropus poliocephalus and *Ninox strenua* are both listed under the *Flora and Fauna Guarantee Act 1988*. Latham's Snipe has been nominated for listing and is covered by migratory bird treaties with China and Japan.

In order of abundance, the most widely detected native animals (in most reserves) were Common Brushtail Possum *Trichosurus vulpecula*, Common Ringtail Possum *Pseudocheirus peregrinus*, Striped Marsh Frog *Limnodynastes peronii*, Southern Brown Tree Frog *Litoria ewingii*, Garden Skink *Lampropholis guichenoti*, Little Forest Bat *Vespadelus vulturnus*, Superb Fairy-wren *Malurus cyaneus*, Common Froglet *Crinia signifera*, Eastern Yellow Robin *Eopsaltria australis*, Delicate Skink *Lampropholis delicata*, and Weasel Skink *Saproscincus mustelinus*. All were recorded at ten or more reserves. The two possum species were recorded at 15 reserves, which was the maximum at which they

Fig. 3. Red Fox *Vulpes vulpes*. Photo from remote camera.

Fig. 4. Fallow deer *Cervus dama*. Photo from remote camera.

could have been recorded, given the other reserve, Karkarook, was surveyed only for frogs. The most common exotic species detected were Red Fox *Vulpes vulpes* (Fig. 3), Common Blackbird *Turdus merula* and Black Rat *Rattus rattus*, which were recorded at 11 or more reserves. Other 'outsiders' included Eastern Dwarf Tree Frog *Litoria fallax*, which was found at three sites in Koomba Park, Vermont South, and Fallow Deer *Cervus dama* (Fig. 4), which was detected in two small reserves: Baluk Willam and Cardinia Creek Parklands.

While the animals were recorded across the study area certain patterns emerged. Large native mammal species such as macropods, Common Wombat *Vombatus ursinus* and Koala *Phascolarctos cinereus* were recorded mostly in Berwick parklands. It should be noted, however, that Black Wallaby *Wallabia bicolor* and Eastern Grey Kangaroo *Macropus giganteus* were both recorded in Corhanwarrabul Wetlands, the southernmost reserve in Dandenong Valley parklands. A similar pattern occurred with Agile Antechinus *Antechinus agilis* and Bush Rat *Rattus fuscipes* which, with the exception of hair samples in Dandenong Valley's Bushy Park, were recorded only in reserves in Berwick parklands. The only recording of Sugar Glider *Petaurus breviceps* outside Berwick parklands was also at Bushy Park. Dusky Antechinus *Antechinus swainsonii* was recorded only in the east and only in the two smaller reserves of Selby and Baluk Willam.

Verreaux's Tree Frog *Litoria verreauxii* and Peron's Tree Frog *Litoria peronii* were recorded only in Berwick parklands, and Victorian Smooth Froglet *Geocrinia victoriana* mainly so, the only recording outside this area being at Koomba Park. Four reptiles were recorded in one reserve: Bougainville's Skink *Lerista bougainvillii*, Eastern Three-lined Skink *Acritoscincus duperreyi*, Southern Water Skink *Eulamprus tympanum* and White-lipped Snake *Drysdalia coronoides*. The Tree Dragon *Amphibolurus muricatus* was recorded only in two reserves, while McCoy's Skink *Anepischetosia maccoyi* was recorded only in Berwick parklands.

The introduced mammal, Red Fox, was recorded across the study area, while others such as Black Rat and House Mouse *Mus musculus* were prevalent in Dandenong Valley and Braeside, but less so further into the rural landscape.

All techniques used, except for hair funnel, detected one or more species which was not detected by any other technique (Table 4). However, at a reserve level, hair funnels did make a difference. As an example, a hair sample was responsible for the only detection of Agile Antechinus at Bushy Park, and for the only detection of Dusky Antechinus at Baluk Willam.

Cameras recorded all of the mammal species (other than bats) that were detected by any method (Table 5). They were most successful (or equal first) in recording 15 of the species, while the hair funnels proved most successful for four of the small mammals species and spotlighting for arboreal mammals.

One outcome sought from the survey was some assessment of whether the survey regime was appropriate to gather the necessary management data. Table 6 provides a comparison of findings from this survey with the results of previous observations as entered into the VBA.

Even though this study did not concentrate on birds, from a future directions perspective it

Table 3. Species detected during the survey, by park or reserve, and the number of parks or reserves in which they were recorded. The * indicates exotic species and # indicates that the species is listed in the Advisory List of Threatened Vertebrate Fauna in Victoria – 2013

Common Name	Scientific Name	Baluk Willam NCR	Braeside Park	Bushy Park	Cardinia Creek Parklands	Cardinia Reservoir Park	Churchill National Park	Corhanwarrabul Wetlands	Dandenong Police Paddocks reserve	Jells Park	Karkarook Park	Koomba Park	Lysterfield Park	Selby G190 BR	Shepherds Bush	Upper Beaconsfield NCR	Wattle Park	Number of parks in which species were recorded
Amphibian																		
Common Froglet	*Crinia signifera*	X	X	X	X		X		X	X	X	X	X		X			11
Eastern Dwarf Tree Frog	*Litoria fallax*											X						1
Peron's Tree Frog	*Litoria peronii*	X					X						X					3
Southern Brown Tree Frog	*Litoria ewingii*	X	X	X	X	X	X		X	X		X	X	X	X			12
Southern Bullfrog (ssp. unknown)	*Limnodynastes dumerilii*	X	X		X	X	X		X				X					7
Southern Toadlet #	*Pseudophryne semimarmorata*						X						X					2
Spotted Marsh Frog	*Limnodynastes tasmaniensis*		X	X	X				X	X		X	X		X			8
Striped Marsh Frog	*Limnodynastes peronii*	X	X	X	X		X		X	X	X	X	X		X		X	12
Verreaux's Tree Frog	*Litoria verreauxii verreauxii*	X			X		X		X				X					5
Victorian Smooth Froglet	*Geocrinia victoriana*						X		X			X	X					4
Bat																		
Chocolate Wattled Bat	*Chalinolobus morio*					X												1
Gould's Wattled Bat	*Chalinolobus gouldii*			X	X				X	X								4
Grey-headed Flying-fox#	*Pteropus poliocephalus*		X	X					X	X							X	5
Large Forest Bat	*Vespadelus darlingtonii*												X			X		2
Lesser Long-eared Bat	*Nyctophilus geoffroyi*		X		X	X	X		X	X			X					7
Little Forest Bat	*Vespadelus vulturnus*	X	X	X	X	X	X		X	X		X	X	X	X			12
Southern Forest Bat	*Vespadelus regulus*					X												1
White-striped Freetail Bat	*Tadarida australis*	X		X	X	X	X		X				X					7

Table 3. (cont.)

Common Name	Scientific Name	Baluk Willam NCR	Braeside Park	Bushy Park	Cardinia Creek Parklands	Cardinia Reservoir Park	Churchill National Park	Corhanwarrabul Wetlands	Dandenong Police Paddocks reserve	Jells Park	Karkarook Park	Koomba Park	Lysterfield Park	Selby G190 BR	Shepherds Bush	Upper Beaconsfield NCR	Wattle Park	Number of parks in which species were recorded
Bird																		
Australian Magpie	*Cracticus tibicen*		X	X	X		X	X	X				X	X		X		9
Australian Owlet-nightjar	*Aegotheles cristatus*						X						X	X				3
Australian Wood Duck	*Chenonetta jubata*				X	X												2
Bassian Thrush	*Zoothera lunulata*							X		X			X		X	X		5
Beautiful Firetail	*Stagonopleura bella*			X														1
Brown Thornbill	*Acanthiza pusilla*			X	X							X						3
Brush Bronzewing	*Phaps elegans*												X					1
Buff-banded Rail	*Gallirallus philippensis*			X								X						2
Cattle Egret	*Ardea ibis*		X															1
Common Blackbird*	*Turdus merula*	X		X	X			X	X	X		X	X	X	X	X	X	12
Common Bronzewing	*Phaps chalcoptera*		X	X	X		X	X	X	X			X		X			9
Common Myna*	*Acridotheres tristis*			X	X				X	X		X						5
Common Starling*	*Sturnus vulgaris*			X	X			X	X			X						5
Crimson Rosella	*Platycercus elegans*				X									X				2
Dusky Moorhen	*Gallinula tenebrosa*											X						1
Eastern Rosella	*Platycercus eximius*				X													1
Eastern Spinebill	*Acanthorhynchus tenuirostris*				X							X						2
Eastern Yellow Robin	*Eopsaltria australis*				X	X		X	X	X		X	X	X	X	X		10
European Goldfinch*	*Carduelis carduelis*									X								1
European Greenfinch*	*Carduelis chloris*									X								1
Fan-tailed Cuckoo	*Cacomantis flabelliformis*				X	X			X									3
Galah	*Eolophus roseicapilla*				X													1
Gang-gang Cockatoo	*Callocephalon fimbriatum*				X													1
Golden Whistler	*Pachycephala pectoralis*											X						1

Table 3. (cont.)

Common Name	Scientific Name	Baluk Willam NCR	Braeside Park	Bushy Park	Cardinia Creek Parklands	Cardinia Reservoir Park	Churchill National Park	Corhanwarrabul Wetlands	Dandenong Police Paddocks reserve	Jells Park	Karkarook Park	Koomba Park	Lysterfield Park	Selby G190 BR	Shepherds Bush	Upper Beaconsfield NCR	Wattle Park	Number of parks in which species were recorded
Grey Butcherbird	*Cracticus torquatus*				X			X	X				X	X				5
Grey Currawong	*Strepera versicolor*			X		X		X	X			X	X					6
Grey Fantail	*Rhipidura albiscapa*				X			X		X		X	X	X	X			7
Grey Shrike-thrush	*Colluricincla harmonica*	X			X	X			X	X		X	X	X	X			9
House Sparrow*	*Passer domesticus*									X								1
Latham's Snipe #	*Gallinago hardwickii*		X															1
Laughing Kookaburra	*Dacelo novaeguineae*	X		X	X	X			X				X	X				7
Little Raven	*Corvus mellori*	X		X	X							X	X		X			6
Little Wattlebird	*Anthochaera chrysoptera*									X								1
Magpie-lark	*Grallina cyanoleuca*		X		X		X		X	X			X					6
Masked Lapwing	*Vanellus miles*				X										X			2
Nankeen Night Heron #	*Nycticorax caledonicus hillii*											X						1
Noisy Miner	*Manorina melanocephala*		X		X				X				X					4
Pacific Barn Owl	*Tyto javanica*		X															1
Pacific Black Duck	*Anas superciliosa*		X									X						2
Pied Currawong	*Strepera graculina*									X		X	X					3
Powerful Owl #	*Ninox strenua*				X		X						X		X	X		5
Purple Swamphen	*Porphyrio porphyrio*				X					X	X							3
Rainbow Lorikeet	*Trichoglossus haematodus*				X													1
Red Wattlebird	*Anthochaera carunculata*				X		X	X	X			X			X			6
Red-browed Finch	*Neochmia temporalis*							X		X		X	X	X				5
Rock Dove*	*Columba livia*									X			X					2
Sacred Kingfisher	*Todiramphus sanctus*											X						1
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*				X													1
Song Thrush*	*Turdus philomelos*														X			1

Table 3. (cont.)

Common Name	Scientific Name	Baluk Willam NCR	Braeside Park	Bushy Park	Cardinia Creek Parklands	Cardinia Reservoir Park	Churchill National Park	Corhanwarrabul Wetlands	Dandenong Police Paddocks reserve	Jells Park	Karkarook Park	Koomba Park	Lysterfield Park	Selby G190 BR	Shepherds Bush	Upper Beaconsfield NCR	Wattle Park	Number of parks in which species were recorded
Southern Boobook	*Ninox novaeseelandiae*	X			X		X			X			X		X		X	7
Spotted Pardalote	*Pardalotus punctatus*				X													1
Spotted Turtle-Dove*	*Streptopelia chinensis*		X	X	X			X		X		X						6
Striated Pardalote	*Pardalotus striatus*				X													1
Sulphur-crested Cockatoo	*Cacatua galerita*		X		X		X					X			X			5
Superb Fairy-wren	*Malurus cyaneus*			X	X	X	X	X	X	X		X	X	X	X	X		12
Tawny Frogmouth	*Podargus strigoides*		X					X		X		X	X		X		X	7
White-browed Scrubwren	*Sericornis frontalis*							X	X			X	X	X	X	X		7
White-eared Honeyeater	*Lichenostomus leucotis*							X										1
White-faced Heron	*Egretta novaehollandiae*								X									1
White-plumed Honeyeater	*Lichenostomus penicillatus*											X						1
White-throated Treecreeper	*Cormobates leucophaeus*											X						1
Willie Wagtail	*Rhipidura leucophrys*				X										X			2
Yellow-faced Honeyeater	*Lichenostomus chrysops*				X													1
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*				X													1
Mammal (except bat)																		
Agile Antechinus	*Antechinus agilis*	X		X									X	X				4
Black Rat*	*Rattus rattus*		X	X			X	X	X	X		X	X		X	X	X	11
Black Wallaby	*Wallabia bicolor*	X			X	X	X	X	X				X	X		X		9
Bush Rat	*Rattus fuscipes*	X		X		X							X	X				5
Common Brushtail Possum	*Trichosurus vulpecula*	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	15
Common Ringtail Possum	*Pseudocheirus peregrinus*	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	15

Table 3. (cont.)

Common Name	Scientific Name	Baluk Willam NCR	Braeside Park	Bushy Park	Cardinia Creek Parklands	Cardinia Reservoir Park	Churchill National Park	Corhanwarrabul Wetlands	Dandenong Police Paddocks reserve	Jells Park	Karkarook Park	Koomba Park	Lysterfield Park	Selby G190 BR	Shepherds Bush	Upper Beaconsfield NCR	Wattle Park	Number of parks in which species were recorded
Common Wombat	*Vombatus ursinus*	X			X	X	X						X	X		X		7
Cow*	*Bos taurus*		X						X				X					3
Dog*	*Canis lupus familiaris*			X	X				X	X		X	X		X			7
Dusky Antechinus	*Antechinus swainsonii*	X												X				2
Eastern Grey Kangaroo	*Macropus giganteus*	X			X	X	X	X	X				X	X		X		9
European Hare*	*Lepus europeaus*									X			X		X			3
European Rabbit*	*Oryctolagus cuniculus*		X		X		X		X	X			X					6
Fallow Deer*	*Cervus dama*	X			X													2
House Cat*	*Felis catus*	X		X				X					X			X		5
House Mouse*	*Mus musculus*		X	X				X	X	X					X		X	7
Koala	*Phascolarctos cinereus*						X						X					2
Red Fox*	*Vulpes vulpes*	X	X	X	X	X	X	X	X	X		X	X	X		X	X	14
Short-beaked Echidna	*Tachyglossus aculeatus*	X	X		X	X	X		X				X	X		X		9
Sugar Glider	*Petaurus breviceps*	X		X					X				X			X		5
Swamp Rat	*Rattus lutreolus*							X					X					2
Reptile																		
Blotched Bluetongue Lizard	*Tiliqua nigrolutea*		X				X		X				X					4
Bougainville's Skink	*Lerista bougainvillii*		X															1
Common Snake-necked Turtle	*Chelodina longicollis*													X				1

Table 3. (cont.)

Common Name	*Scientific Name*	Baluk Willam NCR	Braeside Park	Bushy Park	Cardinia Creek Parklands	Cardinia Reservoir Park	Churchill National Park	Corhanwarrabul Wetlands	Dandenong Police Paddocks reserve	Jells Park	Karkarook Park	Koomba Park	Lysterfield Park	Selby G190 BR	Shepherds Bush	Upper Beaconsfield NCR	Wattle Park	Number of parks in which species were recorded
Delicate Skink	*Lampropholis delicata*	X	X	X	X	X	X		X	X		X	X		X			11
Eastern Three-lined Skink	*Acritoscincus duperreyi*	X																1
Garden Skink	*Lampropholis guichenoti*	X	X	X	X	X	X	X	X	X		X	X		X			12
Lowland Copperhead	*Austrelaps superbus*		X		X				X					X				4
McCoy's Skink	*Anepischetosia maccoyi*	X			X		X		X				X					5
Southern Water Skink	*Eulamprus tympanum*	X																1
Tree Dragon	*Amphibolurus muricatus*		X						X									2
Weasel Skink	*Saproscincus mustelinus*	X	X	X	X		X	X	X	X		X	X		X			11
White-lipped Snake	*Drysdalia coronoides*												X					1

Table 4. Total species richness of each vertebrate group and the method by which they were detected. The figure in brackets represents the number of species that were detected by this method alone.

Class/Order	Total species richness	Camera audio	Camera visual	Frog survey	Hair funnels	Harp trap	Spotlight	Tiles/Tin
Bats	8					6(5)	3(2)	
Birds	64	32(12)	44(22)				19(8)	
Amphibians	10	3(0)		10(2)			8(0)	
Mammals (excl. Bats)	21		21(3)		12(0)		12(0)	
Reptiles	12		2(0)				1 (1)	10(7)
Total species detected	115	35(12)	67(25)	10(2)	12(0)	6(5)	43(11)	10(7)

Table 5. Number of reserves at which mammal species (excluding bats) were detected by the survey techniques of remote camera (visual), hair funnel and spotlighting. Red indicates the 'most successful' technique for that species and 'n' is the total number of reserves in which that technique was used.

Common Name	Camera visual (n=15)	Hair funnel (n=13)	Spotlighting (n=14)
Agile Antechinus	3	4	
Black Rat	10	2	3
Black Wallaby	9	1	4
Bush Rat	2	5	
Common Brushtail Possum	12	5	12
Common Ringtail Possum	9	1	14
Common Wombat	7		2
Cow	3		
Dog	6	1	
Dusky Antechinus	1	2	
Eastern Grey Kangaroo	9		6
European Hare	3		
European Rabbit	6	1	1
Fallow Deer	2		1
House Cat	5		
House Mouse	2	5	
Koala	1		1
Red Fox	13	4	5
Short-beaked Echidna	9		1
Sugar Glider	1		5
Swamp Rat	2	1	
Total species	21	12	12

is worth noting that there are some 40 birds of conservation significance (DSE 2013) recorded in the VBA for the study area. While most of these are wetland birds, there are also a number of woodland species.

Community involvement

It is estimated that around 115 volunteers from 26 community/environmental organisations took part in the survey in one or more activities. Additionally, some 15 Parks Victoria staff also participated in on-site visits and activities. Volunteers indicated association with the following groups:

- Animalia
- Berwick Area Parklands
- Birdlife Melbourne
- Cardinia Catchment Landcare
- Cardinia Creek Landcare
- Field Naturalists Club of Victoria
- Friends of Baluk Willam
- Friends of Blind Creek Billabong
- Friends of Braeside
- Friends of Damper Creek Reserve
- Friends of Dandenong Valley Parklands
- Friends of Hazel Vale Valley
- Friends of Sassafras Creek
- Friends of Selby Nature Conservation Reserve
- Friends of Wattle Park
- Glen Eira Environment Group
- Knox City Council
- Knox Environment Society
- Latrobe Valley Field Naturalists
- Lysterfield Park Volunteers
- Monash University Biological Society
- Parks Victoria
- Ringwood Field Naturalists Club
- Southern Dandenong Landcare Group
- Southern Ranges Environment Alliance
- Wild Days Wildlife Shelter

The volunteers and PV staff took part in 137 outings (Table 7), plus untold hours of video analysis. Many took part in more than one activity and some took part in all activities.

We estimate a commercial value for the project at $160 000. While this is a rough estimate, it nevertheless provides a scale of the effort involved and a background for judging if the outcomes were commensurate with this investment.

Discussion

The project set out to develop a vertebrate fauna list, to involve the community, to assess the success of the survey techniques and to provide a view of the implications for the future of monitoring projects.

Our results enabled the development of a significant fauna list for the reserves and focus areas within the study area. Combined with the records in the VBA, it can be demonstrated that over 300 vertebrate species use or have used the reserves and their surrounds.

Focus area results provide data on the locations of species using these reserves and allow assessments of which habitats may be important. As well as overall species richness, we found that these urban parks are providing habitat for species of conservation significance.

Table 6. Comparison between the species recorded in this study and those recorded in the same reserves in the Victorian Biodiversity Atlas as at August 2016. Birds have not been included in this comparison because this study did not include a full bird survey. (This survey recorded 67 bird species and the VBA 227.)

Class/Order	No. of species this study	Number of species in VBA (Aug 2016)	Common name of species in VBA, but not detected in this study
Amphibians	10	8	Growling Grass Frog
Bats	8	9	Eastern Broad-nosed Bat
Mammals (excl. Bats)	21	21	Brown Rat, Platypus, Southern Brown Bandicoot, Water Rat.
Reptiles	11	17	Black Rock Skink, Common Blue-tongued Lizard, Cunningham's Skink, Eastern Small-eyed Snake, Southern Grass Skink, Tiger Snake, White's Skink

If VBA records are included, then the total vertebrate species of conservation significance to have been recorded in the study area (over time) is over 40.

As well as the occurrence of native species, the survey recorded some exotic, over-abundant or invasive species. The Red Fox, Domestic Cat, European Rabbit and Noisy Miner were all detected. Their impacts are considered as potentially threatening processes under the *Flora and Fauna Guarantee Act* 1988. The presence of other immigrants also provides food for thought. The distribution of Eastern Dwarf Tree Frog *Litoria fallax* was historically in coastal and adjacent areas from southern New South Wales to central-eastern Queensland (Cogger 2000). The species was first found in Victoria in Moorabbin (Gillespie and Clemann, 2000), some 600 km from its then known home range. There is concern about the effect that 'imported' frogs may have on native populations (Gillespie and Clemann 2000). The Fallow Deer is the most widely distributed of the deer species in Australia (Moriarty 2004). Management of deer presents a conundrum for land managers as society is divided as to whether the animals are an asset or liability (Moriarty 2004).

The involvement of volunteers (citizen scientists) in natural resource and environmental science has been longstanding (McKinley *et al.* 2015). The outcomes have been shown to improve natural resource management and environmental protection and are making an increasing contribution to scientific papers (McKinley *et al.* 2015).

Our project demonstrates that there is a volunteer resource available and willing to make a sizeable commitment to biodiversity monitoring. We also found organisations and individuals that were willing to provide financial and material support. We were able to successfully engage individuals largely through existing environmental groups and networks. We did not formally pursue with the volunteers what their their motives were for joining the program or how they perceived its success or their levels of satisfaction. The project's appeal was possibly enhanced by its varying opportunities for participation. Camera analysis work provided a participation opportunity and a long-term commitment to a variety of survey techniques for those with either time constraints or other reasons for not being able to participate in fieldwork. The shorter time requirement of spotlighting/bat trapping likewise afforded an opportunity for the time-constrained, as well as a hands-on experience for families and younger participants.

Informally, feedback from volunteers was positive, with many relishing the opportunity to be involved. The main negative was the ultimate size of the program, its intensity and length of commitment. In our zeal to make a large contribution, it appears that on occasions we moved to a situation where participation was more of an onerous experience than a positive one.

Our survey techniques are commonly used in these types of surveys and well described (e.g. NPANSW 2001). We avoided catch and release methods, aside from bat traps, largely because we lacked the resources. Instead we used remote cameras which are now being used widely in wildlife management (Swann *et al.* 2004).

Table 7. Activities in which volunteers participated and an estimate of the extent of their involvement.

Activity	Estimated number of volunteers	Workload
Camera – set up	10	273 cameras deployed and retrieved in 48 outings
Camera – image analysis	28	33,000 10-second videos analysed
Hair-funnels	10	360 hair-tubes deployed and collected in 20 outings
Bat trapping and spotlighting	71	36 bat trap deployments at 24 sites and spotlighting at 42 sites in a total of 12 outings
Frog Surveys	27	45 sites surveyed 8 times each in around 45 outings
Reptile surveys	46	55 quadrats checked in 12 outings
Total	115	137 outings

They can provide a basic knowledge of an animal's presence, are relatively cheap and are safe for humans and animals (Swann and Perkins 2014). Multiple techniques are required to effectively assess species richness (Catling *et al.* 1997, Garden *et al.*, 2007) and our results support that notion.

While our results demonstrated the value in using multiple methods, there is still a chance that species remained undetected in the study area overall or in individual reserves and focus areas. As an example, a dead Agile Antechinus was reported at Braeside in 2015 near one of our study sites (Oliphant, pers. comm., May 2015). We recorded none in this reserve.

Historical records and the VBA (Table 6) indicate that some species previously recorded in the study area, were not recorded during this survey. Although these species may no longer be there, it raises the possibility that our techniques or survey regime did not adequately cater for all possibilities.

The frog findings, with the exception of *L. fallax*, were typical for the area and consistent with a previous study in Churchill and Lysterfield Parks (Drury and Patterson 2010). Growling Grass Frog *Litoria raniformis*, which is listed in the VBA as being recorded in the study area, was not detected. This species is not well represented in the Melbourne Water frog census (MW 2015), either for the study area or the metropolitan area at large. While the use of the Melbourne Water Frogwatch program methodology made this survey quite thorough, the study occurred in a period of below average rainfall. Bureau of Meteorology observations for nearby Scoresby show that five of the eight months over the survey period had below average rainfall, with the total for that time being 49 mm below average. The availability of water (Ficetola and De Bernardi, 2004) and the hydroperiod (the amount of time a wetland retains water) (Snodgrass *et al.* 2000), have been shown to be important determinants of frog activity.

The VBA shows a number of records for Eastern Broad-nosed Bat *Scotorepens orion* in the heathland focus area at Braeside. We recorded none. Most are recorded through bat trapping. While we used that technique, it was only for one night per location and therefore this and other bat species could have been easily missed. There were four terrestrial mammals recorded in the VBA that were not recorded in this survey. Two of these, Platypus *Ornithorhynchus anatinus* and Water Rat *Hydromys chrysogaster*, are aquatic and were unlikely to be recorded in this study regime, save for an incidental observation in a creek or wetland. Two VBA records of the Brown Rat *Rattus norvegicus* exist for Dandenong Valley, one by cage trap and the other an incidental sighting. The species is not well recorded and perhaps a more focused effort and the use of other techniques would be needed if the existence or otherwise of the mammal was deemed to be important for decision-making purposes.

Long-nosed Bandicoot *Perameles nasuta* and Southern Brown Bandicoot *Isoodon obesulus* were historically recorded in the Dandenong Valley (Wallis 1994), with the VBA containing records of the latter at Churchill NP in the 1980s. Given the extent of the camera survey and the success of this method for this species at other sites by the FSG and in other surveys (e.g. Smith and Coulson 2012), it seems likely that these species are no longer present.

Other medium-sized native species such as Tasmanian Bettong *Bettongia gaimardi*, Eastern Quoll *Dasyurus viverrinus* and Spot-tailed Quoll *Dasyurus maculatus* have also historically been recorded in the Dandenong Valley (Wallis 1994). Unsurprisingly the VBA does not record any of these species in the survey areas. The first two are believed to be extinct on the mainland, now occurring only in Tasmania (Rose 1986; Fancourt *et al.* 2013). The Spot-tailed Quoll is considered endangered in Victoria (DSE 2013) and is mainly recorded in south-western Victoria, the Otway Ranges, South Gippsland (the Strzelecki Ranges), north-eastern Victoria and East Gippsland (DSE 2003). Although we did not detect this species, an unconfirmed sighting of a Spot-tailed Quoll was reported near the Cardinia Creek in 2015 (S. Czarka pers. comm., June 2015), which raises the possibility of this species being in the area, or at least occasionally visiting.

Excluding birds, the reptile survey has revealed the largest discrepancy between our

findings and VBA records (Table 6). Two species of snake and five species of lizard were recorded in the VBA, but not in our survey. These 'missing' species were detected largely by incidental observation, but Elliott traps, active searching and pitfall with drift fence also provided records. Therefore there is an argument to suggest that multiple techniques are necessary to improve the chances of detecting reptile presence.

A number of other factors could have affected the detection of a species. Clearly, the species list would have been increased significantly if we had been able to carry out a formal bird survey (e.g. Loyn 1986). A stratified sampling regime (Quinn and Keough 2006), as opposed to our unstratified grid positions, may be more appropriate to detect target species that prefer a specific habitat. Variations of the same technique, such as vertical orientation of ground-based cameras (Taylor *et al.* 2014) or the use of tree-based cameras for arboreal species (Harley *et al.* 2014; Drury 2016), may be in order.

We now have an opportunity to reflect on how this project developed and how useful the output will be. We can reflect upon both what went right and on those areas where improvements might be made. It is important that this process takes place. During this analysis we need to consider whether the results of this survey are good enough (in quality and/or completeness) to link with decision-making and policy-making processes. This link is seen to be essential (Niemelä 2000; Schmeller *et al.* 2009; Lindenmayer *et al.* 2012). Data users need to be convinced that the data are useful and reliable (Cohn 2008). If volunteer interest is to be maintained, volunteers need to know that their data are used and valued by scientists and policy makers (Bell *et al.* 2008).

Overall, the results provide opportunities and set challenges for the delivery of PV's strategies. Our survey plus other records (e.g. VBA) show that all parklands can lay claim to species of conservation concern. Likewise all parklands harbour species listed as threats. Whatever priorities are determined, the support programs put in place will require a monitoring component. Well-organised citizen scientist involvement has been proved capable of making a significant contribution to this monitoring.

Acknowledgements

Thanks to Parks Victoria for giving us the opportunity to participate in the program. Thanks to Rangers-in-charge David Collins, John Goodman and Des Lucas, and all their staff, for their support and participation. Thanks especially to PV staff Sandie Czarka, Mick Van de Vreede, Michelle Judd, Glen Oliphant, Garry Lalor, Andrew Van Vloten and Vanessa Bluett for their huge contribution to the project.

Thanks to FSG members Graeme Patterson and Su and Peter Dempsey for managing the camera and hair funnel program. I also thank Graeme for his considerable contribution to data management. Thanks to Ray Gibson, Russell Thompson and Ian Kitchen for managing the spotlighting and bat trapping. Thanks to David De Angelis for managing the frog census and to Kathy Himbeck, John Harris and David De Angelis for organising the reptile surveys.

Thanks to Hans Brunner for analysing the animal hairs; and to Mark Antos, Sally Bewsher and Ray Gibson for their helpful comments on this paper.

Thanks to Parks Victoria, Melbourne Water and the Knox Environment Society for their financial support, and Boral Industries, John Poppins and Ross O'Meara for the donation of equipment.

A special thank-you to all the volunteers from the FNCV and other community and environmental groups, who gave up their time to participate in the fieldwork or other tasks.

The survey was carried out in accordance with Department of Environment and Primary Industries research permits 10006308 and 10007541 and Wildlife and Small Institutions Animal Ethics Committee approvals 12.12 and 3.15.

References

Bell S, Marzano M, Cent J, Kobierska H, Podjed P, Vandzinskaite D, Reinert H, Armaitiene A, Grodzińska-Jurczak M and Muršič M (2008) What counts? Volunteers and their organisations in the recording and monitoring of biodiversity. *Biodiversity and Conservation* 17, 3443–3454.

Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, and Shirk J (2009) Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* 59, 977–984.

Catling PC, Burt RJ and Kooyman R (1997) A Comparison of Techniques used in a Survey of the Ground-dwelling and Arboreal Mammals in Forests in North-eastern New South Wales. *Wildlife Research* 24, 417–432.

Cogger HG (2000) *Reptiles and amphibians of Australia.* (Reed New Holland: Sydney)

Cohn JP (2008) Citizen science: can volunteers do real research? *BioScience* 58, 192–197.

Department of Sustainability and Environment (DSE) (2003) Action Statement Flora and Fauna Guarantee Act 1988, Spotted-tailed Quoll *Dasyurus maculatus*. Revised edn. No 15, Victorian Government, Melbourne.

Department of Sustainability and Environment (2013) Advi-

sory List of Threatened Vertebrate Fauna in Victoria 2013. Victorian Government, Melbourne.
Drury R and Patterson G (2010) Parks—a haven for frogs? *The Victorian Naturalist* **127**, 201–204.
Drury R (2014) Fauna monitoring in eastern metropolitan parks. *The Victorian Naturalist* **131**, 28–30.
Drury R (2016) Surveying for arboreal mammals in the Grampians National Park and adjacent reserves: Fauna Survey Group contribution no. 28. *The Victorian Naturalist* **133**, 64–71.
Fancourt BA, Hawkins CE and Nicol SC (2013). Evidence of rapid population decline of the eastern quoll (*Dasyurus viverrinus*) in Tasmania. *Australian Mammalogy* **35**, 195–205.
Ficetola GF and De Bernardi F (2004) Amphibians in a human dominated landscape: the community structure is related to habitat features and isolation. *Biological Conservation* **119**, 219–230.
Garden JG, McAlpine CA, Possingham HP and Jones DN (2007) Using multiple survey methods to detect terrestrial reptiles and mammals: what are the most successful and cost-efficient combinations? *Wildlife Research*, **34**, 218–227.
Gillespie GR and Clemann N (2000) The Eastern Dwarf Tree Frog *Litoria fallax* (Peters) (Anura: Hylidae): a recent introduction to Victoria?. *The Victorian Naturalist* **117**, 60–62.
Harley DKP, Holland GJ, Hradsky, BA and Antrobus JS (2014) The use of camera traps to detect arboreal mammals: lessons from targeted surveys for the cryptic Leadbeater's Possum. (*Gymnobelideus leadbeateri*). In *Camera trapping: Wildlife management and research*, pp. 233–244 Eds P Meek, P Fleming, G Ballard, P Banks, A Claridge, J Sanderson and D Swann. (CSIRO Publishing: Collingwood).
Lindenmayer DB, Gibbons P, Bourke MA, Burgman M, Dickman CR, Ferrier S, Fitzsimons J, Freudenberger D, Garnett ST, Groves C, Hobbs RJ ,Kingsford RT, Krebs C, Legge S, Lowe AJ, Lean RM, Montambault J, Possingham H, Radford J, Robinson D, Smallbone L, Thomas D, Varcoe T, Vardon M, Wardle G, Woinarski J and Zerger A (2012) Improving biodiversity monitoring. *Austral Ecology* **37**, 285–294.
Loyn RH (1986) The 20-minute search—a simple method for counting forest birds. *Corella* **10**, 58–60.
Macak PV, Bruce MJ and Loyn RH (2012) Community finding fauna—naturalists groups contributing to research on the response of fire to fauna. Black Saturday Victoria 2009—natural values fire recovery program. Department of Sustainability and Environment, Heidelberg, Victoria.
McKinley DC, Miller-Rushing AJ, Ballard HL, Bonney R, Brown H, Evans DM, French RA, Parrish JK, Phillips TB, Ryan SF and Shanley LA (2015). Investing in citizen science can improve natural resource management and environmental protection. *Issues in Ecology* **2015**, 19.
Melbourne Water (MW) (2012) *Healthy Waterways Waterwatch Frog Census Handbook* (2012) http://frogs.melbournewater.com.au/content/library/get_involved/Frog_Census_Handbook_2012.pdf.
Melbourne Water (2015) Healthy Waterways Waterwatch Frog Census http://frogs.melbournewater.com.au/
Moriarty A (2004) The liberation, distribution, abundance and management of wild deer in Australia. *Wildlife Research* **31**, 291–299.
Niemelä J (2000) Biodiversity monitoring for decision-making. In *Annales Zoologici Fennici*, pp. 307–317. (Finnish Zoological and Botanical Publishing Board: Helsinki).
National Parks Association of New South Wales (NPANSW) (2001) *Community Biodiversity Survey Manual*. 2nd edn. (NPANWS Inc: Sydney South)
Parks Victoria (2013) *Parks Victoria—Shaping our future*. (Parks Victoria: Melbourne)
Parks Victoria (2015a) What we manage. http://parkweb.vic.gov.au/about-us/who-we-are/what-we-manage
Parks Victoria (2015b) Native Plants and Animals. http://parkweb.vic.gov.au/park-management/environment/native-plants-and-animals
Quinn GP and Keough MJ (2006) *Experimental design and data analysis for biologists*. (Cambridge University Press: Cambridge)
Rose RW (1986) The Habitat, Distribution and Conservation Status of the Tasmanian Bettong, *Bettongia Gaimardi* (Desmarest). *Wildlife Research* **13**, 1–6.
Schmeller DS, Henry P, Julliard R, Gruber B, Clobert J, Dziock F, Lengyel S, Nowicki P, Déri E, Budrys E, Kull T, Tali K, Bauch B, Settele J, Van Swaay C, Kobler A, Babij V, Papastergiadou E, Henle K (2009) Advantages of Volunteer-Based Biodiversity Monitoring in Europe. *Conservation Biology* **23**, 307–316.
Smith JK and Coulson G (2012) A comparison of vertical and horizontal camera trap orientations for detection of potoroos and bandicoots. *Australian Mammalogy* **34**, 196–201.
Snodgrass JW, Komoroski MJ, Bryan AL and Burger J (2000) Relationships among isolated wetland size, hydroperiod, and amphibian species richness: implications for wetland regulations. *Conservation Biology* **14**, 414–419.
Swann DE, Hass CC, Dalton DC, Wolf SA (2004) Infrared-triggered cameras for detecting wildlife: an evaluation and review. *Wildlife Society Bulletin* **32**, 357–65.
Swann DE and Perkins N (2014) Camera trapping for animal management and monitoring: a review of applications. In *Camera trapping: Wildlife management and research*, pp. 3–12. Eds P Meek, P Fleming, G Ballard, P Banks, A Claridge, J Sanderson and D Swann. (CSIRO Publishing: Collingwood).
Taylor BD, Goldingay RL and Lindsay JM (2014) Horizontal or vertical? Camera trap orientations and recording modes for detecting potoroos, bandicoots and pademelons. *Australian Mammalogy* **36**, 60–66.
Wallis RL (1994) From Melbourne to Mornington—A survey of vertebrate fauna in parks and reserves. School of Aquatic Science and Natural Resource Management, Deakin University, Victoria, Australia. *Technical Paper 1994/1*.

Received 29 June 2017; accepted 17 August 2017

Association of a White-banded Jumping Spider *Hypoblemum albovittatum* (Salticidae: Araneomorphae: Aranaea) with an Anemone Stinkhorn Fungus *Aseroë rubra* (Phallaceae: Basidiomycota)

Introduction

Scientists have carried out research on the sensory biology of spiders for well over a century with some interesting results. Spiders in general are known now to have a good variety and number of sensory receptors. Most spiders have eight eyes, which in some species give nearly 360° vision, although other species have poor vision (e.g. Barth 2002; Framenau *et al.* 2014); cave-dwelling spiders may have little or no vision (Doran *et al.* 2001; Egan 2013; Framenau, *et al.* 2014). Certain spiders once were thought to be deaf (e.g. Pritchett 1904); but, some salticid spiders have a good sense of hearing, demonstrating an acoustic-triggered startle response (Shamble *et al.* 2016). The fact that some male salticids, e.g. *Maratus* species (Otto and Hill 2015), give remarkably colourful courtship displays suggests they have at least some degree of colour vision. This has been confirmed by several recent studies (e.g. Taylor 2016; Zurek *et al.* 2015). Salticid spiders are well-known to have elaborate vision-based predatory strategies (Cross *et al.* 2009; Zurek *et al.* 2015; Whyte and Anderson 2017). The giant-eyed Deinopidae species are also heavily dependent on vision for their net-casting behaviour (Whyte and Anderson, 2017). Spiders can discriminate between arthropod prey species, refusing to attack certain toxic species such as some cockroaches, butterflies and millipedes (pers. obs.; Vasconcellos-Neto and Lewinsohn 1984) suggesting they may have a sense of taste, although experiments by Toft (1999) suggest aversion memory is short-lived.

Spiders are well-known for their sense of temperature (e.g. Pocock 1893; Barth 2002). The detailed experiments conducted by Pritchett (1904) suggested the sense of smell is detected at numerous points of the body, including the legs. It now is believed that chemical communication probably is used by all spiders in functions such as attraction, detection, luring and avoidance (Cross *et al.* 2009; Uhl 2013). It is now known that a number of spiders use their olfactory senses to determine which prey to take, how much venom is needed for each, and even whether they have enough venom in their venom glands (Wullschleger and Nentwig 2002). The vital role of volatile pheromones in spider reproduction has been well studied in a number of species (Rao and Tietjen 1987; Prenter *et al.* 1994; Papke *et al.* 2001; Schulz 2004; Roberts and Uetz 2005; Gaskett 2007; Stoltz *et al.* 2007; Xiao *et al.* 2009; Chinta *et al.* 2010; Jerhot *et al.* 2010; Xiao *et al.* 2010; Hutton and Rypstra 2016). Spiders also have a number of well-developed mechanoreceptors (Barth 2002).

Observations

Around midday on 25 August 2016—a mild, dry, late-winter day with a temperature range of 2.9–26.6°C—a White-banded Jumping Spider *Hypoblemum albovittatum* was noticed jerkily moving around on a concrete tree-ring around the base of a small *Bougainvillea* bush in the author's back garden. The ring was surrounded by a Buffalo grass *Stenotaphrum secundatum* lawn and the soil inside the ring was covered by a layer of pine bark chips. The spider, although continuing to move around, remained in one area on the north-west margin of the ring. On closer inspection, a small but mature and colourful Anemone Stinkhorn *Aseroë rubra* was seen low down near ground level just inside the ring (Fig. 1). Observation over a period of half an hour showed that the spider remained mainly on the higher elevation concrete ring, but also moved around the fungus on the bark chips. The spider also moved over the outer rim of the concrete at times, where it couldn't see the fungus, but always returned closer to the fungus. At this point I had to leave but, on returning about 2 ½ hours later, it (apparently the same spider) was still near the fungus and remained in its vicinity for at least forty minutes. During the periods of observation, it never moved more than about 150 mm from the fungus, but it never came

Fig. 1. A 7 mm female White-banded Jumping Spider *Hypoblemum albovittatum* on the inside of a concrete tree-ring in close proximity to a mature Anemone Stinkhorn *Aseroë rubra* growing in bark chips.

closer than about 30 mm from the fungus. Two days later the fungus was decomposing and the spider could not be seen. At no time was the spider observed to capture any prey.

Discussion of author's observations

Hypoblemum albovittatum is one of at least 27 species of Salticidae observed in the Dora creek catchment in western Lake Macquarie (pers. obs.). This species has been observed frequently to range widely across the ground, up house walls, windows, trees, posts, fences etc. in pursuit of small arthropods such as chironomids (Chironomidae), mosquitos (Culicidae), ants (Formicidae), cluster bugs (Lygaeidae) and fungus gnats (Sciaridae) (pers. obs.). My observations of *H. albovittatum* show that its movements appear to be more or less random while foraging. It is evident that the spider observed here was not moving about randomly, but was persistently remaining within the vicinity of a sapromyiophilic stinkhorn fungus. Stinkhorn fungi of various species are known to emit volatile compounds such as oligosulphides, phenols, indoles, cresols and some of their derivatives (Johnson and Jürgens 2010; Pudil *et al.* 2014) that are malodorous to humans and act as attractants to flies. No other spider of any species was seen to exhibit such behaviour and no other explanation for this behaviour was thought likely. These observations suggest that salticid spiders such as *H. albovittatum* may not only have a good sense of smell but, possibly, an associated memory of smell. Whether the association of a smell with increased chance of catching prey is a learned behaviour or an instinctive behaviour is not known, but it is unlikely that the spider observed here had ever come in contact with *A. rubra* in the past as this is an uncommon fungal species in this area and was the first seen in this garden in thirteen years. It is possible that the spider had learned over previous hours or days that prey was more readily available near this particular stinkhorn. The fact that the spider moved out of the line of sight several times but then returned to close proximity suggests that it was odour rather than vision that was attracting the spider. As stinkhorn fungi decompose they are known to reduce their volatile emissions and to alter their composition (Johnson and Jürgens 2010), which may account for the absence of the spider at the fungus decomposition stage.

The increasing number of publications about olfaction within spiders suggest this sense is widespread in them. It is possible that any sense

of taste is associated with smell as both involve chemoreception and it is possible that spiders use both types of receptors in assessing the palatability of a given prey item. An observation of a possible unpalatability reaction was observed where a *H. albovittatum* spider was seen to pounce on a crawling termite but released it within about one tenth of a second.

References

Barth FG (2002) *A Spider's World: Senses and Behavior*, (translated from: *Sinne und Verhalten aus dem Leben einer Spinne*, 2001). (Springer-Verlag: Berlin)

Chinta SP, Goller S, Lux J, Funke S, Uhl G and Schulz S (2010) The sex pheromone of the wasp spider *Argiope bruennichi*. *Angewante Chemie International Edition*. **49**, 2033–2036.

Cross FR, Jackson RR and Pollard SD (2009) Vampire spiders: the advantage of being smelly. *American Arachnology* **78**, 15.

Doran NE, Richardsnn AMM and Swain R (2001) The reproductive behaviour of *Hickmania troglodytes*, the Tasmanian cave spider (Araneae, Austrochilidae). *Journal of Zoology* **253**, 405–418.

Egan J (2013) Cavern Creatures. *Australian Geographic* **112**, 22.

Framenau VW, Baehr BC and Zborowski P (2014) *A Guide to the Spiders of Australia*. (Reed New Holland: Sydney)

Gaskett AC (2007) Spider sex pheromones: emissinn, reception, structures and functions. *Biological Reviews* **82**, 26–48.

Hutton BA and Rypstra AL (2016) Courtship and the use of pheromones by *Pholcus manueli* (Araneae: Pholcidae). Short Communications. *Journal of Arachnology* **44**, 92–95.

Jerhot E, Stoltz JA, Andrade MCB and Schulz S (2010). Acylated serine derivatives: a unique class of arthropod pheromones of the Australian Redback Spider, *Latrodectus hasselti*. *Angewante Chemie International Edition* **49**, 2037–2040.

Johnson SD and Jürgens A (2010) Convergent evolution of carrion and faecal scent mimicry in fly-pollinated angiosperm flowers and a stinkhorn fungus. *South African Journal of Botany* **76**, 796–807.

Otto JC and Hill DE (2015) Two new peacock spiders nf the *calcitrans* group from southern Queensland (Araneae: Salticidae: Euophryinae: *Maratus*). *Peckhamia* **121**, 1–34.

Papke MD, Riechert SE and Schulz S (2001) An airborne female pheromone associated with male attraction and courtship in a desert spider. *Animal Behaviour* **61**, 877–886.

Pocock RI (1893) Further notes and observations upon the instincts of some common English Spiders. *Nature* **49**, 60–63.

Prenter J, Elwood RW, Montgomery WI (1994) Assessments and decisions in *Metellina segmentata* (Araneae: Metidae): evidence of a pheromone involved in mate guarding. *Behavioural Ecology and Sociobiology* **35**, 39–43.

Pritchett AH (1904) Observations on Hearing and Smell in Spiders. *American Naturalist* **38**, 859–867.

Pudil F, Uvira R and Janda V (2014). Volatile Compounds in stinkhorn (*Phallus impudicus* L. ex pers.) at different stages of growth. *European Scientific Journal* **10**, 163–171.

Rao L and Tietjen WJ (1987) Preliminary isolation of male-inhibitory pheromone of the spider *Schizocosa ocreata* (Araneae, Lycosidae). *Journal of Chemical Ecology* **13**, 237–244.

Roberts JA and Uetz GW (2005) Information content of female chemical signals in the wolf spider, *Schizocosa ocreata*: male discrimination of reproductive state and receptivity. *Animal Behaviour* **70**, 217–223.

Schulz S (2004) Semiochemistry of spiders. In *Advances of chemical ecology*, pp. 110–150. Eds RT Cardé and JG Millar. (Cambridge University Press: Cambridge, UK)

Shamble PS, Menda G, Golde JR, Nitzany EL, Walden K, Beatus T, Elias DO, Cohen I, Miles RN and Hoy RR (2016) Airborne Acoustic Perception by a Jumping Spider. *Current Biology* **26**, 2913–2920.

Stnltz JA, McNeil JN and Andrade MCB (2007) Males assess chemical signals to discriminate just-mated females from virgins in redback spiders. *Animal Behaviour* **74**, 1669–1674.

Taylor LA, Amin Z, Maier EB, Byrne KJ and Morehouse NI (2016) Flexible color learning in an invertebrate predator: Jumping spiders can learn to prefer or avoid red during foraging. *Behavioral Ecology* **27**, 520–529.

Toft S (1999) Prey choice and spider fitness. *The Journal of Arachnology* **27**, 301–307.

Uhl G (2013) Spider Olfaction: Attracting, Detecting, Luring and Avoiding. In *Spider Ecophysiology*, pp. 141–157. Ed W Nentwig. (Springer: Berlin, Heidelberg)

Vasconcellos-Neto J and Lewinsohn TM (1984) Discrimination and release nf unpalatable hutterflies by *Nephila clavipes*, a neotrnpical orb-weaving spider. *Ecological Entomology* **9**, 337–344.

Whyte R and Andersnn G (2017) *A Field Guide to Spiders of Australia*. (CSIRO Publishing: Clayton South, Victoria)

Wullschleger B and Nentwig W (2002) Influence of venom availability on a spider's prey-choice behaviour. *Functional Ecology* **16**, 802–807.

Xiao Y-H, Zhang J-X and Li S-Q (2009) A twn-component female-based pheromnne of the spider *Pholcus beijingensis*. *Journal of Chemical Ecology* **35**, 769–778.

Xiao Y-H, Zhang J-X and Li S-Q (2010) Male-specific (Z)-9-tricosene stimulates female mating behavior in the spider *Pholcus beijingensis*. *Proceedings of the Royal Society*, Series B **277**, 3009–3018.

Zurek DB, Cronin TW, Taylor LA, Byrne K, Sullivan M and Morehouse NI (2015) Spectral filtering enables trichromatic vision in colourful jumping spiders. *Current Biology* **25**, 403–404.

Terry Annable
Avondale College of Higher Education
582 Freemans Drive
Cooranbong, NSW 2265
tannable@avondale.edu.au

Soldier crabs versus toadfish

At Urunga, on the mid-north coast of New South Wales, a favourite occupation for young and old is to observe the movement and activities of soldier crabs *Mictyris* sp. As at so many other localities along the coast, great numbers of these crabs cluster at low tide (Fig. 1). Urunga provides a unique opportunity to observe soldier crabs at close quarters from its boardwalk (Fig. 2). This elevated platform leads from the caravan park, across sand flats and through the mangroves, to the magnificent surf beach that stretches north and south from the mouth of the Bellinger and Kalang rivers.

Fig. 2. The Urunga boardwalk.

During March 2017, fairly late in the afternoon, many fully grown soldier crabs were observed on the sand flats, and at the same time and a little further out from the shore at the edge of the mangroves, smaller specimens, presumably of the same species, were bunched in substantial numbers at the water's edge. As we watched, we became aware of several toadfish *Tetractenos* sp. in the shallows. As they patrolled slowly along the grooves in the corrugated sand

Fig 1. Soldier crabs at the water's edge and two toadfish (arrowed) at top left corner.

where the water was three or four centimetres deep, they appeared to be watching the crabs.

One of the toadfish suddenly made a lunge toward the crabs and there was an altercation for one or two seconds, followed by a retreat by both parties; no apparent damage done. This happened two or three times more, and then a few minutes later, a lunge by one of the fish was more successful, as a crab was observed scuttling away from the rest—minus one claw! We could see the claw in the mouth of the fish. Several more of these attacks were seen but none appeared to be successful. It was also noted that in one area, following a 'fish lunge', the crabs became more wary and retreated from the water as soon as the fish approached. There were 12 or more toadfish in the immediate area but we saw only two or three of them actively hunting soldier crabs. These fish were an overall sandy colour and barely spotted, whereas the non-active fish present were distinctly spotted. We surmised that there might have been two toadfish species present.

We did not see the hunting activities again when we visited the area at low tide on the subsequent three days. However, on one of those visits, as we leaned over the rail, we spoke to a local fellow and he asked if we had seen the fish hunting the crabs. He commented that he had lived all his life at Urunga and had never seen such predatory activity, until the same day that we observed it.

Alan Monger
10 Hiscock Court
Benalla, Victoria 3672

Discovering Australian Flora: An Australian National Botanic Gardens Experience

by Fanny Karouta-Manasse

Publisher: *CSIRO Publishing, Clayton South, Victoria, 2017. 104 pages, paperback, colour photographs. ISBN 9781486307814. RRP $35.00*

This book began with the author's desire to share with family and friends in the northern hemisphere some of what she had seen in her walks in the Australian National Botanic Gardens (ANBG), Canberra. However, encouragement from an author friend led Fanny Karouta-Manasse to write and publish this book for a wider audience. The book is pictorial in format with limited text adding richness to its images, and is a good demonstration of how much can be learnt from a visit to the Gardens. Text is kept simple and easy to read, explaining the different plant groupings in the Gardens and some characteristics and history of the Australian flora.

The brief Introduction explains the mission of the ANBG: to inspire, inform and connect people with nature. With the publication of her book, Fanny shows the ANBG has been successful in this mission. Hopefully, the book will inspire others to visit the Gardens and connect with the diversity and uniqueness of our flora, and to recognise the importance of protecting it. The Introduction also affords a glimpse into how the ANBG facilitates habitats to showcase flora that normally is unavailable to the region. Arid Australian plants are featured in the Red Centre garden '... where an open, sunny winter aspect combined with the use of large boulders and rock outcrops provides the heat and air circulation to enable many plants from arid Australia to be grown' (page 5).

The section on plant groupings introduces readers to the reasons why certain plants are grouped together: for example, to allow for taxonomic or ecologic comparisons. The horticultural grouping demonstrates the contribution and potential of endemic flora to industry,

while the ethnobotanical grouping shares some of the traditional knowledge of Indigenous Australians. The endangered species grouping highlights that many species may disappear due to habitat loss, and require human assistance for survival through resources such as the National Seed Bank.

The largest section of the book introduces us to the genera *Eucalyptus* and *Acacia* (which dominate the Australian landscape) and to the uniqueness of our flora and some of its important adaptations, including to fire and nutrient-poor soils. Many of our plant species rely on fire to reproduce, but the term fire, Fanny explains, is more complex than most realise and is often used when referring to a 'pattern of burning' in a fire regime. Some plant species have the ability to sprout from buds released from hormonal repression following defoliation by fire, insect attack or drought. Some species survive by serotiny or geospory, terms that are conveniently defined in the book, as is the term scleromorphy, an adaptation that arises in response to nutrient-poor soils but is also a secondary adaption to drought and fire. There is a lot to learn from reading this book and/or a visit to the Gardens.

Fanny also presents a section on 'Some residents and visitors to the Gardens'. Find out that red flowers are not necessarily a method of attracting birds but rather a way to avoid bees! This section has many beautiful photographs showing the wide array of fauna to be met during a visit to the gardens: birds, butterflies, moths, wallabies and kangaroos, echidnas, water dragons, skinks, snakes and more.

A short conclusion explains that only a small part of what is known of our Australian plants

can be presented in this book, which, nevertheless, hopes to encourage readers to discover our unique flora. The conclusion is followed by a sizeable section of 'Photos of plants listed by family'. *Discovering Australian Flora* essentially documents one person's discovery of what the ANBG has to offer and would be a lovely memento of a trip to the Gardens for fortunate visitors. It also allows readers to share their trip with others without the hard work of taking good photos and organising them into a slide show.

This is a lovely little book, stemming from a lovely idea.

Maria Gibson
School of Life and Environmental Sciences,
Deakin University,
221 Burwood Highway,
Burwood, Victoria 3125